WORKING MEMORY AND VERBAL LEARNING IN INDIVIDUALS WITH AND WITHOUT LEARNING DIFFICULTIES

by

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FAIR USE AND AUTHOR'S PERMISSION STATEMENT

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LIST OF ABBREVIATIONS

Abbreviation	Description
LD	Learning Disorder
ADHD	Attention Deficit Hyperactivity Disorder
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, 5^{th} Edition
WM	Working Memory
DS	Digit Span
AR	Arithmetic
SD	Standard Deviation
CVLT-II	California Verbal Learning Test, Second Edition
SEN	Special Education Needs
WISC-V	Wechsler Intelligence Scale for Children, 5^{th} Edition
WISC-III	Wechsler Intelligence Scale for Children, 3^{rd} Edition
KBIT-2	Kaufman Brief Intelligence Test-Second Edition
IQ	Intelligence Quotient
BTVLT	Bergen-Tucson Verbal Learning Test
CVLT-C	California Verbal Learning Test-Children Edition
WAIS-IV	Wechsler Intelligence Scale, 4^{th} Edition
ANOVA	Analysis of Variance

ABSTRACT

A learning disorder (LD) or attention deficit hyperactivity disorder (ADHD) greatly impacts the lives of the individuals with them. This study focuses on examining the differences between working memory and verbal learning abilities in college age participants with and without LD or ADHD. It was predicted that the LD/ADHD group would perform more poorly than the control group on working memory measures and verbal learning measures. It is also predicted that there will be a correlation between working memory and verbal learning. Participants were recruited from the Psychology Department at Texas State University. A total of 10 participants were in the LD/ADHD group and a total of 43 participants were in the control group without LD or ADHD. One participant was excluded from the LD/ADHD group because of incomplete data and two participants were excluded from the control group due to testing errors. The working memory index from the Wechsler Adult Intelligence Scale 4^{th} Edition (WAIS-IV) were used to assess working memory. Verbal learning was assessed using the California Verbal Learning Test, Second Edition (CVLT-II). Results showed that there was a significant difference between groups on the recognition task of the CVLT-II and there was a significant correlation between the total recalled scale of the CVLT-II and the arithmetic subtest of the WAIS-IV. Results indicate that the control group is more efficient at coding new information and that a relationship exists between working memory and verbal learning.

CHAPTER I

Introduction

Learning disorders (LD) and attention deficit/hyperactivity disorder (ADHD) greatly impact the lives of those who have them. In general, the group of individuals with learning disorders is less likely to finish high school, attend college, and improve their quality of life. Connor (2012) stated that only 11% of students with LD attend a four-year university, and of those, only 28% graduate. Secondary education is associated with increased income and better quality of life. Research on the success of individuals with Attention Deficit/Hyperactivity Disorder (ADHD) also suggests their education and work history is negatively affected. Gjervan, Torgersen, Nordahl, and Rasmusses (2012) studied a clinical population of 149 individuals and found that 48% of the sample population reported junior high as their highest level of completed education, compared to 29.8% of the general population in Norway reporting the same. Only 8.2% of their sample population reported earning a college or university degree, compared to 20.8% of the general population reporting earning a degree. Within the general population, 72% of individuals reported their primary income comes from full-time work. Only 22.2% of the sample population reported their primary income deriving from full-time work. They also noted that only 17.4% of their sample population reported receiving stimulant-based treatment by the age of 18. Their research suggests individuals with ADHD are less likely to graduate from a university or college and are less likely to have full-time work as their primary source of income.

LD is diagnosed when an individual experiences difficulty in learning and using academic skills that are not better explained by another disorder such as low intellectual functioning or developmental delays. Learning disorders are broken into three possible diagnoses: specific learning disorder with impairments in reading, specific learning disorder with impairments in written expression, or specific learning disorder with impairments in mathematics. An individual must experience a symptom for at least 6 months with difficulty persisting despite interventions. Symptoms may include one of the following: inaccurate or slow reading; difficulty with reading comprehension; difficulty with spelling; difficulty with written expression; difficulty with number sense, number facts, or calculations; and difficulty with mathematical reasoning (American Psychiatric Association, 2013). According to The Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM–5; American Psychiatric Association [APA], 2013), LD affects between 5% and 15% of children in most cultures. The LD prevalence for adults is unknown but appears to be around 4%.

ADHD is diagnosed when an individual experiences a pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development. The symptoms should be present for at least 6 months, must be observed in multiple settings, should be observed before age 12, and should not be better explained by another disorder such as anxiety or depression. The diagnosis can present in three ways: primarily inattentive presentation, primarily hyperactive-impulsive presentation, or a combined presentation. Inattentive symptoms may include failing to give close attention to details or making careless mistakes; difficulty sustaining attention; difficulty listening; failing to follow directions; failing to complete work, assignments, chores, or other tasks; reluctance engaging in tasks requiring a high level of mental effort; being easily distracted; losing necessary items for a task; or being forgetful. Hyperactivity and impulsivity symptoms may include: fidgetiness, inappropriately leaving their seat, running or climbing in inappropriate situations, difficulty playing quietly, difficulty being still for extended periods of time, excessive talking, blurting out answers or responses inappropriately, difficulty waiting their turn, interrupting others, or intruding on others (American Psychiatric Association, 2013). According to The DSM-5, ADHD affects 5% of children and 2.5% of adults in most cultures.

Previous research on the cognitive differences in students with and without LD show that working memory and short-term memory are impaired in individuals with LD. Jefferies and Everatt (2004) showed that students with special education needs, including reading specific learning disorders, performed worse on working memory tasks than their control group with no special education needs. Beneventi, Tonnessen, and Ersland (2008) showed that children with dyslexia, a reading learning disorder, had deficits in short-term memory. Their study included fMRI data and behavioral evidence indicating that there are underlying cognitive differences between groups with and without dyslexia. Specifically, there seems to be a deficit in the phonological loop.

Verbal learning and memory is also related to phonological processing. Oyler, Obrzut, Arve, and Asbjornsen (2012) examined verbal learning and memory functioning in adolescents with reading LD. They wanted to examine the role that development, experience, and coping skills played in learning for adolescent individuals with LD. They found that although the students had more reading experience, they were still showing deficits in verbal learning when compared to adolescent students without LD. This study also assessed using phonemic and semantic cues for recall and found that the LD group did not recall more information when a phonemic or semantic cue was given. This suggests that the LD group has a deficit in using phonemic features to recall words.

The majority of research on learning difficulties, including LD and ADHD, is focused on school-aged children. There is limited research available on adolescents, college-age students, and adults with these disorders. Learning difficulties greatly affect those who suffer these issues and limit their potential, yet there is currently a lack of effective treatment methods for the cognitive impairments observed in these disorders.

CHAPTER II

Literature Review

Both learning disorders (LD) and attention-deficit hyperactivity disorder (ADHD) functionally impair the learning process. Both conditions are associated with higher levels of stress and anxiety, as well as lower graduate rates for high school and college (Nelson & Gregg, 2012). This leads to an overall decrease in the quality of life among individuals who have LD and ADHD. Currently, there are limited treatment options for cognitive improvement among students who suffer from LD or ADHD. The purpose of this study is to gain a better understanding of the cognitive differences in working memory and verbal learning between a group of college students who have LD or ADHD and college students who do not have LD or ADHD.

Working Memory

Working memory refers to one's ability to maintain information and use it in some cognitive process. The construct is similar to short-term memory, but differs in the ability to manipulate or use the information being processed. Working memory may be conceived of as including three components (Matlin, 2005). The three parts are the phonological loop, visuospatial sketchpad, and central executive. The central executive controls encoding and retrieval of information from the phonological loop and visuospatial sketchpad. The central executive does not store information; instead, it helps with planning and coordinating information. The central executive also plays a role in attention and planning, as well as suppressing irrelevant information not needed for the task at hand. The phonological loop is responsible for storing verbal information, while the visuospatial sketchpad is responsible for storing visual information. The three areas of working memory each have an important role in allowing us to encode and recall information (Jefferies & Everatt, 2004).

Jefferies and Everatt (2004) examined working memory abilities in learning disorders in children. Their study included 87 children, of which 47 had learning impairments requiring special education needs (SEN). Of the SEN children included in their study, 21 individuals were diagnosed with dyslexia. The non-dyslexic SEN children had other specific learning disorders, including dysgraphia, attention problems, emotional/behavioral problems, general language difficulties, or literacy deficits. The remaining individuals did not have any known learning difficulties. The researchers assessed the children's working memory abilities using the Working Memory Test Battery for Children, which is described as a norm referenced psychometric test to assess working memory in individuals aged from 5-15 years old. The battery also measures how abilities were spread among the three components of the working memory model: central executive, the phonological loop, and the visuospatial sketchpad. Two measures from the Dyslexia Screening Test were also used to assess motor and visuospatial coordination. Attention symptoms were tested using the color-word interference task and bespoke interference task. The Phonological Ability Battery was used to assess alliteration, rhyme, and non-word reading. The Bangor Dyslexia Test was used to assess left/right coordination and hand-eye coordination. (Jeffries & Everatt, 2004)

Jeffries and Everatt (2004) found several significant results. The dyslexic SEN and non-dyslexic SEN groups performed worse on phonological processing tasks than the control group. Interestingly, the older children in the non-dyslexic SEN group were not significantly different from the control group in alliteration scores. As children develop, the alliteration abilities of those with non-dyslexic learning disabilities improve to normal abilities for their age group. As expected, the non-dyslexic SEN group performed worse than the dyslexic SEN group on visuo-spatial and motor coordination tasks. There was not a significant difference between the dyslexic and control group. Both SEN dyslexic and non-dyslexic SEN groups performed worse on working memory and executive functioning tasks. The digit span backward task showed the greatest difference between groups. The dyslexic group had the lowest scores, followed by the non-dyslexic SEN group, while the control group performed the best. When age was accounted for in the secondary age group, the difference between the non-dyslexic SEN and control group was non-significant. This again suggests that, as they develop, the non-dyslexic SEN group performs as expected. In general, the results showed that the students with learning disabilities performed worse on cognitive tasks, including working memory tasks, than their peers without learning disabilities. Students with dyslexia showed more cognitive weaknesses over all (Jefferies & Everatt, 2004).

Beneventi, Tonnessen, and Ersland (2009) did an fMRI study on short-term memory in phonological storage and serial rehearsal in children with dyslexia. They propose that dyslexia is a neurobiological disorder and used fMRI data to show differences in brain behavior during cognitive tasks. While the children performed memory tasks, Beneventi, Tonnessen, and Ersland gathered fMRI data from 11 children with a dyslexia diagnosis and 13 children without a learning disorder diagnosis. The children were first assessed for general intelligence and reading abilities. The full intelligence scores were estimated from four subtests from the Norwegian Wechsler Intelligence Scale for Children 3rd Edition (WISC-III) equivalent test. Reading abilities were assessed using a pseudoword reading test, a reading test with rapid word presentation, a phoneme deletion test, and a listening comprehension test. The children who met criteria for reading specific learning disorder based on their IQ score and tested reading abilities were included in the LD group. The children then performed short-term memory tasks during an fMRI scan. The tasks were letter matching, letter probe, and sequence probe. Stimuli were presented both visually and verbally, and the tasks became increasingly more difficult. Behavioral observations and scan results were analyzed (Beneventi et al., 2009).

Beneventi et al. (2009) found behavioral and neurobiological differences between the two groups. The LD group had reduced speed and accuracy on behavioral tasks when compared to the control group. The LD group had significantly lower scores on behavioral tasks than the control group. The fMRI data revealed that the control group had more areas of the brain activated during the tasks than the LD group. The control group showed more activation in the right middle frontal gyrus, precentral gyrus, superior parietal lobule, middle temporal gyrus, and the occipital cortex when compared to the LD group. In general, they found behavioral and neurobehavioral evidence that short-term memory is impaired in children with dyslexia (Beneventi et al., 2009).

Alderson, Hudec, Patros, and Kasper (2013) examined working memory deficits in adults with ADHD. They had a sample of 37 undergraduate subjects, 21 of which had a diagnosis of ADHD. The participants with ADHD who used medication prescribed for ADHD were asked to discontinue medication for 24 hours prior to completing the study session. In the session, participants were screened for ADHD and any other psychological illness, to minimize extraneous variables. Subjects were assessed for general intellectual functioning using the Kaufman Brief Intelligence Test-Second Edition (KBIT-2). The model for working memory used in this study states that working memory involves the temporary storage and manipulation of information and is comprised of the central executive with two subsystems, the phonological loop and the visuospatial sketchpad. Researchers used scales to assess separately the two components of the central executive: phonological loop and visuospatial sketchpad. A measure for both phonological loop and visuospatial sketchpad was developed and the combination was used to represent central executive. Visuospatial working memory was assessed by a modified activity based on a task developed by Rapport and colleagues in which the participants must respond to changing visual stimuli. Phonological working memory was assessed using a modified test similar to the letter-number sequencing. Both working memory tasks were administered on a computer. The participants started the session with the KBIT-2, had a short break, then concluded the session with the working memory tasks on the computer. The participants were allowed to take breaks between tasks, or as needed throughout the session (Alderson et al., 2013).

Alderson et al. (2013) found significant differences in working memory abilities between adults with ADHD and adults without ADHD. Findings indicated that the central executive working memory was significantly lower in adults with ADHD than their peers without ADHD. Participants with ADHD performed worse on phonological working memory tasks than visuospatial working memory tasks in general. However, the ADHD group never performed equal to or better than the individuals in the control group without ADHD. The results suggest that working memory is a cognitive weakness in adults with ADHD (Alderson et al., 2013).

Verbal Learning

Verbal learning refers to the ability to learn new information and recall it later when the information is presented orally. It is one of the most widely used methods of teaching. Verbal learning requires an individual to understand and encode new information, as well as retrieve it at a later time. Some research has suggested that individuals with learning difficulties, such as dyslexia, struggle more than their peers at encoding and retrieving information they have gained verbally.

Oyler, Obrzut, and Asbjornsen (2012) examined verbal learning abilities in adolescents with and without reading learning disorders. Their research suggested that most research on this topic focuses on children, with few researchers studying adolescent or adult verbal learning abilities. Researchers recruited 20 students with a reading learning disorder and 20 students without a learning disorder. Exclusion criteria included the presence of any other psychological disorder. Participants were also screened for intelligence and reading abilities, and only individuals with IQ scores between 90 and 110, were included. The students in the reading disorder group had been previously assessed and diagnosed by reliable sources. The study focused on results from the Bergen-Tucson Verbal Learning Test (BTVLT) – English version (Oyler et al., 2012), a new assessment tool modeled after the California Verbal Learning Test (CVLT) (Delis, Kramer, Kaplan, & Ober, 2000) to be administered to both English and Norwegian-speaking students. The BVLT has been used in research but is not available for commercial use. The assessment consists of students learning a list of words over five trials, and then a distractor list is given over one trial. Students must then recall the original list of words in an immediate recall trial and a delayed recall trial. The assessment also includes a recognition section in which they must state if a given word was on the original list.

Results show that the control group was more proficient at the learning task. The initial recall for the first five trials were compared between groups and results showed that there was not a significant difference on the first trial, but students in the control group were able to recall more words from the list for the remaining trials. This indicates that students without reading disabilities were able to learn more words at a faster rate than students with reading disorders. Researchers analyzed data for total recall of both trial 5 and trial 7. The results indicated that students without a reading disorder were able to learn more words in the immediate and delay recall. The results also show that both groups appeared to retain a comparable portion of learned words. This suggests that students with a reading disorder were not as efficient at learning words, but that both groups maintained what they learned. Their results suggest that verbal learning is impaired in adolescent ages students with a reading disorder (Oyler et al., 2012).

Kramer, Knee, and Delis (2000) assessed verbal learning in children with dyslexia. Their study focused on three questions: “Are children with dyslexia deficient in their acquisition, retention, or retrieval of new verbal information? Do children with dyslexia display evidence for less efficient encoding? Are Children with dyslexia more vulnerable to interference?” (Kramer et al., 2000). Their study consisted of a sample group of 44 boys and 13 girls with a previous diagnosis of dyslexia and a matched control group of 88 boys and 26 girls without dyslexia. Participants were assessed using the California Verbal Learning Test – Children Edition (CVLT-C) (Delis, Kramer, Kaplan, & Ober, 1994).

These researchers found significant differences between their two groups. The children with dyslexia were able to recall fewer words on trial 2 and trial 5. The delayed recall scores indicate that the control group was able to learn more words than the dyslexic group. However, both groups retained the same portion of words learned over the 5 trials. The recognition section of the test suggested that those in the control group encoded information better than the dyslexic group by being able to correctly identify more words from the target list than the dyslexic group. Researchers also assessed if the interference words from the distractor list were recalled or identified in the recognition task and found no significant difference between groups. Their research suggests that children with dyslexia have a deficit in verbal learning when compared to a control group without dyslexia, but that they are not more susceptible to interference.

The research suggests that individuals with learning difficulties are more likely to have deficits in working memory and verbal learning than individuals without learning difficulties. Very few studies have examined associations between these two cognitive tasks and few have studied these cognitive abilities in adults or college students. The current study will examine whether there is an association between working memory and verbal learning abilities in college undergraduates with and without learning difficulties, and whether adults with learning difficulties maintain these as cognitive weaknesses.

Problem Statement

Learning disorders in college-age individuals are not well understood. The current research investigates the relationship between working memory and verbal learning in individuals with and without LD or ADHD. This research will also assess for differences in working memory abilities and verbal learning in college students with and without LD or ADHD.

Research Hypothesis

It is predicted that the differences in working memory performance will be observed between college students with and without LD or ADHD. It is also predicted that a difference in verbal learning will exist between the groups. I predict those with LD or ADHD will perform more poorly on working memory tasks and verbal learning tasks than peers in the control group. I predict that working memory performance will positively correlate with verbal learning scores, such that individuals with higher working memory scores will have higher verbal learning scores.

CHAPTER III

Research Design and Methods

Research Question and Hypothesis

This study focuses on the relationship between working memory and verbal learning. The primary question was whether a relationship exists between working memory and verbal learning in individuals with and without learning difficulties. It was predicted that those with learning difficulties would have poorer performance on measures of working memory. It was also predicted that individuals with better working memory performance would perform better on verbal learning tasks.

Participants

Participants were volunteers from Texas State University, San Marcos, recruited from the Psychology department. Participants were recruited through an IRB approved mass email with basic information about the study and sign up information provided. Students were offered proof of participation in the study for possible course extra credit. Participants needed to be native English speakers and over the age of 18 to participate. Participants were identified as either having LD or ADHD (LD/ADHD group) or not (Control group) based on their response to a learning difficulty-related question on the demographic information questionnaire. In total, 53 participants were recruited in the study. Of those, 47 participants were female, 5 were male, and one participant did not identify gender. The LD/ADHD group had 10 participants, one of whom was excluded from the study because they did not specify gender, which was needed to produce gender-based scaled scores. A total of 9 participants remained in the LD/ADHD group (all 9 were female). 5 participants reported having a diagnosis of ADHD, 3 participants reported a diagnosis of LD, and one participant reported a comorbid diagnosis of LD and ADHD. One participant reported taking medication for ADHD on the day of testing. There were 43 participants in the original Control group; however, two were discarded because of testing errors. The final control group had 5 male participants and 36 female participants. The participant ages range from 18 to 54. All participants gave informed consent to participate in the study.

Demographic Questionnaire.

The first section was a demographics survey that consisted of questions assessing basic information such as gender, age, highest level of education, and presence of a learning disability (see Appendix A). These demographic variables were used to determine which group the participant would be placed in. Information was also used to score materials.

Testing Materials

The Wechsler Adult Intelligence Scale 4th Edition (WAIS-IV) Working Memory Index subtests were used to assess the participants working memory index. This index was comprised of two subtests: Digit Span and Arithmetic. The digit span subtest requires participants repeat number sets of increasing difficulty to the examiner over three trials. In the first trial, the participant repeated a set of numbers in the order given. In the second trial, the participants repeated a set of numbers in reverse order. In the third trial, the participants are asked to rearrange the numbers in order from smallest to largest. Each trial was discontinued after the participants miss two consecutive number sequences matched for difficulty. The arithmetic subtest was comprised of verbal mathematic word problems with increasing difficulty that the participant must solve without using paper and pencil in a limited amount of time. Each question had a time limit of 30 seconds and the test was discontinued after three questions in a row were scored with zero, either because the participant gave an incorrect response or went over the allowed time.

The California Verbal Learning Test, Second Edition (CVLT-II) was used to assess verbal learning. The participants were asked to listen to and remember a list of words read aloud by the examiner over 5 trials. For each trial, the examiner read a list of 16 words and the participants were asked to recall the list. The sixth trial introduced a new list, which the participants were asked to recall once. After the sixth trial, the participants were asked to recall the original list without naming words from the second list and the participants were also asked to name items from the list that fit into one of four categories. There was a twenty-minute delay before the next section of the test. After the delay, the participants were asked to recall the original list, and then asked to recall items that fit into one of four categories. The test also had a recognition task, which has a list of words including both target and distractor items that the participant identified as being on the original target list or not.

Procedure

Participants were seated directly across from the examiner. The researcher had two undergraduate research assistants assist in testing subjects. The participant was asked to sign the informed consent form and fill out the demographic questionnaire. The CVLT-II was administered first, followed by the WAIS-IV Working Memory Index. The long delay of the CVLT-II and the recognition portion were administered after the Working Memory Index. Participants were asked who their professor was and the professor was contacted with the name of the participant as proof of participation in the study. A four-digit number randomly generated by a random number generator identified the participant on testing material. The participants were also coded by color for group designation. Participation was anonymous and no identifying information was connected to the raw data.

CHAPTER IV

Results

This study examined the potential differences between individuals with and without LD or ADHD on measures of working memory and verbal learning. The Working Memory Index, digit span subtest, and arithmetic subtest are dependent variables associated with working memory. The CVLT-II total recalled score, short delay, long delay, and recognition scores are dependent variables associated with verbal learning. The Total Recalled score is the cumulative normed score for recall over the first five trials of the CVLT-II.

Hypothesis

It was predicted that the individuals with LD or ADHD would perform more poorly than peers without LD or ADHD on working memory measures and verbal learning measures. It was further predicted that there would be a relationship between working memory and verbal learning. To test this hypothesis, a one-way analysis of variance (ANOVA), was used to compare the two groups on each measure of working memory and verbal learning. A Pearson correlation was also run between the CVLT-II total recalled score measure and the working memory measures. Before running the analyses, the highest and lowest scoring participants in each group were identified as outliers and removed from the statistical analysis.

The correlation between the CVLT-II total recalled score and the Working Memory Index was (r=.275), (p = 0.065). This result approached, but did not reach, statistical significance. The correlation between the digit span subtest and the CVLT-II total recalled score was (r=.041), (p = .786). This result was not significant. The Pearson correlation between the arithmetic subtest and the CVLT-II total recalled score were (r=.350), (p=.017). This is a statistically significant correlation. The results for the Pearson correlation are presented in Table 1. The scatter plot of the correlation data is presented in Table 2.

Table 1

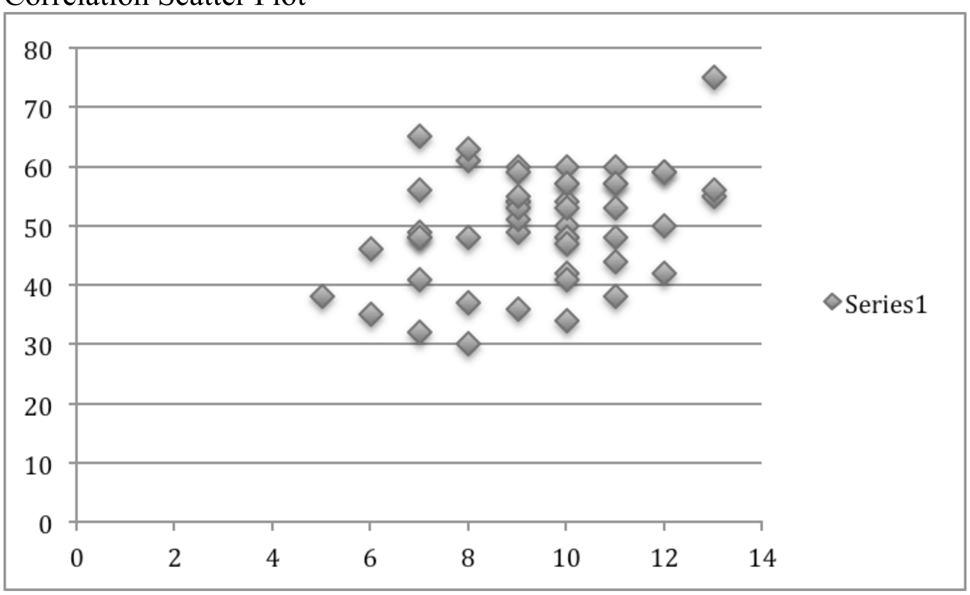
Correlation with CVLT-II Total Recall Score

Working Memory	Pearson Correlation r	p-value
Working Memory Index	.275	.065
Digit Span Subtest	.041	.786
Arithmetic Subtest	.350*	.017

Note. * Indicates significant result

Table 2

Correlation Scatter Plot



The one-way ANOVA was used to test for differences between the two groups for each measure. There was homogeneity of variance, as assessed by Levene's test for equality of variance (p=.089). The recognition abilities between individuals with and without learning difficulty was significant (F(1,44)= 7.091, p=.011). There was homogeneity of variance, as assessed by Levene's test for equality of variance (p=.977), for the measure of CVLT-II long delay. There was not a significant difference between the groups ($F(1,44)=3.201$, $p=.061$). There was homogeneity of variance, as assessed by Levene's test for equality of variance ($p=.941$), for the measure of CVLT-II short delay. There was not a significant difference between the groups ($F(1,44)=.931$, $p=.340$). There was homogeneity of variance, as assessed by Levene's test for equality of variance ($p=.523$), for the measure of CVLT-II total recalled score. There was not a significant difference between the groups ($F(1,44)=.629$, $p=.432$). There was homogeneity of variance, as assessed by Levene's test for equality of variance ($p=.267$), for the measure of working memory index. There was not a significant difference between the groups ($F(1,44)=.143$, $p=.707$). There was homogeneity of variance, as assessed by Levene's test for equality of variance ($p=.967$), for the measure of arithmetic subtest. There was not a significant difference between the groups ($F(1,44)=.135$, $p=.715$). There was homogeneity of variance, as assessed by Levene's test for equality of variance ($p=.912$), for the measure of digit span subtest. There was not a significant difference between the groups ($F(1,44)=.004$, $p=.952$). There was no significant difference between groups on the three subsections of the digit span subtest. There was homogeneity of variance, as assessed by Levene's test for equality of variance ($p=.868$), for the measure of digit span forward. There was not a significant difference between the groups ($F(1,44)=.512$, $p=.478$). There was homogeneity of variance, as assessed by Levene's test for equality of variance ($p=.442$), for the measure of digit span backward. There was not a significant difference between the groups ($F(1,44)=1.724$, $p=.195$). There was homogeneity of variance, as assessed by Levene's test for equality of variance ($p=.824$), for the measure of digit span sequence. There was not a significant difference between the groups

(F(1,44)=.749, *p*=.391).The group mean and standard deviation for each measure are in Table 3. The ANOVA F-statistics and p-value are shown in Table 4.

Table 3

ANOVA Results Between Groups Mean and Standard Deviation

Measure Mean and SD	LD/ADHD Group	Control Group
DS Mean	9.5	9.45
DS SD	1.871	1.867
DS Forward Mean	9.67	10.17
DS Forward SD	1.936	1.909
DS Backward Mean	9.00	8.12
DS Backward SD	2.291	1.706
DS Sequence Mean	8.33	9.07
DS Sequence SD	2.291	2.328
AR Mean	9.67	9.37
AR SD	1.862	1.807
WMI Mean	97.83	96.65
WMI SD	4.021	7.444
CVLT-II Total Recalled Mean	47.00	50.35
CVLT-II Total Recalled SD	11.900	9.319
CVLT-II Short Delay Mean	-0.5	-0.088
CVLT-II Short Delay SD	1.0	0.9733
CVLT-II Long Delay Mean	-0.833	-0.050
CVLT Long Delay SD	0.9309	0.9323
CVLT-II Recognition Mean	-1.417	-0.488
CVLT-II Recognition SD	1.2007	0.7293

Table 4

ANOVA Results

Measure	F-statistic	P-value
CVLT-II Recognition	7.091*	.011*
CVLT-II Total Recalled	.629	.432
CVLT-II Short Delay	.931	.340
CVLT-II Long Delay	3.201	.061
WMI	.143	.707
DS	.004	.952
DS Forward	.512	.478
DS Backward	1.724	.195
DS Sequence	.749	.391
AR	.135	.715

Note. * Indicates significant result

The ANOVA analysis showed that there was one significant difference between the groups. The participants without LD or ADHD performed significantly better than the students with LD or ADHD on the recognition subtest. No other results were statistically significant.

CHAPTER V

Discussion

Having either a learning disorder or attention deficit/hyperactivity disorder is associated with a lower quality of life and poor academic success (Connor, 2012; Gjervan et al., 2012). Many individuals with LD or ADHD do not complete high school or attend a four-year university, and of those who do attend university, the graduation rate is lower. Individuals with LD or ADHD are likely to earn less over their lifetime than peers without LD or ADHD (Connor, 2012; Gjervan et al., 2012).

Previous research suggests there are cognitive differences between individuals with and without LD or ADHD. Students with LD or ADHD demonstrate poorer working memory performance when compared to peers without LD or ADHD (Jefferies & Everatt, 2004; Alderson et al., 2013). Verbal learning abilities have also been shown to be impaired in students with LD (Oyler et al., 2012). However, these differences are not widely studied for college undergraduates.

The current study examined potential differences between college students with and without LD or ADHD on measures of working memory and verbal learning. The study also examined a potential relationship between working memory and verbal learning. It was predicted that participants in the LD/ADHD group would perform more poorly on measures for working memory and verbal learning than peers in the control group. The researcher also predicted there would be a positive correlation between working memory and verbal learning scores.

Analyses indicated no significant difference between the groups of students with and without LD or ADHD on measures of working memory. This is interesting because there is an established body of research demonstrating differences between these two groups in school-aged children (Jefferies & Everatt, 2004; Beneventi et al., 2009). A possible reason for the lack of difference between the groups in the current study is the small sample size of the LD/ADHD group. It is also possible that there is a difference between adults with LD or ADHD that attend or do not attend a university. It is possible that the working memory abilities of individuals with LD or ADHD who attend a university are a personal weakness but do not represent a general weakness. More information is needed in the adult group of individuals with LD or ADHD to assess these possible differences.

Analyses indicated significant differences for only one measure of verbal learning, the CVLT-II recognition task. Recognition tasks assess the degree to which one is able to encode information into long-term memory. These results suggest that the control group of students without LD or ADHD were able to encode the information more effectively than the group with LD or ADHD. There were no other significant differences between the groups. It is interesting that the verbal learning measure did not show a significant difference because it has been observed in younger school aged children (Oyler et al., 2012). Again, the small sample size may account for the lack of a significant result. However, other differences may exist within the group of adults with LD or ADHD that should be explored. The results for verbal learning suggest that there are not differences in the performance from learning, but the control group was able to encode information more efficiently.

A Pearson correlation was used to assess for a relationship between verbal learning and working memory. The only significant correlation was between the arithmetic subtest and verbal learning total recalled score, which were weakly positively correlated. The correlation between the digit span subtest and verbal learning total recalled score was near zero, indicating that there was no relationship between the two measures. The working memory index was close to being significantly correlated with verbal learning total recalled score. These results suggest there is a weak relationship between working memory and verbal learning. The small sample size may have affected the strength of the correlation. A possible relationship between working memory and verbal learning suggests that the two measures may affect one another. More research is needed to establish if one has an affect on the other. If working memory has an affect on verbal learning, it may be possible to improve verbal learning if working memory is improved. The relationship between working memory and verbal learning should be further studied.

There were some limitations in this study. The limitation that may have had the strongest impact on results was the small sample size for the LD/ADHD group. The LD/ADHD group was much smaller than the control group which would affect the external validity of the study because a small sample size is less representative of the population. Another limitation was that the LD/ADHD group was comprised of all females, which again affects external validity because it is more difficult to generalize to the population. A larger and more diverse group would have been ideal for this study.

Another limitation on the group is that the participants were all college undergraduate students and may not represent the general population, especially those in the LD/ADHD adult group. A third group of adults with LD/ADHD that did not attend a university would have added to the external validity of the research. Another limitation for this study was not assessing for LD or ADHD. There was no benefit for the participant to be in one group over the other, therefor, it is unlikely that the participant would feel the need to lie about having a disorder. However, it would be beneficial to ensure that all participants in the LD/ADHD group met criteria for the disorder they stated they were diagnosed with. However, for this study, it may have made recruiting participants challenging if they were required to be in the study for four hours in order to assess for LD or ADHD.

The results from this study suggest that future research should continue to examine potential cognitive differences between adults with and without LD or ADHD. Such studies may include exploring possible differences between adults with LD or ADHD who attend universities versus those who do not attend universities. Understanding the differences within the group of individuals with LD or ADHD may help researchers design teaching methods or cognitive skills training programs to help all students with LD or ADHD become more academically successful.

Other possible studies would include cognitive skills training for working memory. The correlation between working memory and verbal learning suggests that improving one area may improve the other. That suggests there may be an academic benefit for improving working memory in students with LD or ADHD to help them become more efficient verbal learners.

APPENDIX SECTION

APPENDIX A

Age

Gender

Years of Education (12 + ____ yrs in college)

Date of testing

Learning Disability   Yes   NO

If yes, please name specific learning disorder (optional)

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